2009 E2S2 Symposium

Designing, Integrating, and Operating a Microgrid
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Outline

- Microgrid Definition
- Microgrid Benefits
- Testbed Requirements
- Technical Approach
- Results

What is a Microgrid?

General Definition:

- A microgrid is an integrated energy system consisting of interconnected loads and distributed energy resources that can operate in parallel with the grid or in an intentional island mode.

Key Defining Characteristics:

- Integrated distributed energy resources (DERs), capable of providing sufficient and continuous energy to mission critical loads
- Independent controls; island and reconnect with minimal disruption
- Flexible configuration and operation of the power delivery system
- Optimized local DERs, large network loads, and broader power system

What a Microgrid is NOT

- One microturbine in a commercial building
- A group of individual generation sources that are not coordinated, but run optimally for a narrowly defined load
- A load or group of loads that cannot be easily separated from the grid or controlled
- A system that can only operate in isolation from the grid
- Does not have to have thermal (whereas CHP by definition has thermal)

Microgrid Overview

Gen Sets

VAC

Renewable Sources

VDC/VAC

Integration Technology

SYSTEM METERING

SOURCE CONTROL

LOAD CONTROL

SYSTEM PROTECTION

DISTRIBUTION HARDWARE

POWER CONDITIONING

VAC

Base Camp

VAC

Installation

Microgrid Potential Benefits

- IMPROVED RELIABILITY
  - Critical load support
  - Integration of multiple generation sources (legacy and renewable)
- RISK MITIGATION
  - Eliminate dependance upon local utility
  - Integrating available energy sources for backup power
- ELECTRICAL COST REDUCTION
  - Intelligent control for peak shaving
  - Renewable Energy Integration
  - Improved asset utilization by integrating distributed sources

Microgrid Testbed Objective

- Objective – Design, install, and test a scalable microgrid with distributed generation sources and loads

  1. Modeling and Simulation – Software tool to confirm design strategies and solutions
  2. System Controllers – Combination Distribution Management System and Internet resource
  3. Renewable Energy Sources – Combined generation of conventional generation with renewable energy sources.

Microgrid Testbed Requirements

- Improve System Reliability
  - Eliminate single points of failure by using redundant controls
  - Intelligently control sources to meet load requirements
  - Intelligently control loads to avoid system overloads
  - Develop software modeling to predict system limitations and develop appropriate controls
  - Simplify generator synchronization controls by using one controller as opposed to three independent relays (typical scheme)
  - Integrate IEE1547 intertie relay for parallel operation with the utility
  - COTS parts for quick support, replacement

Microgrid Testbed Requirements

- Benefit from System Modeling
  – Develop software models to simulate component and system peformance to identify performance limitations and control solutions
  – Use developed models to design and implement future microgrids or improve existing systems

- Improve Asset Utilization
  – Integrate distributed sources and loads into one distribution system to allow for efficient use of generation assets
  – Improving asset utilization reduces fuel consumption and associated logistics requirements
  – Integrate renewable sources as available

Microgrid Approach

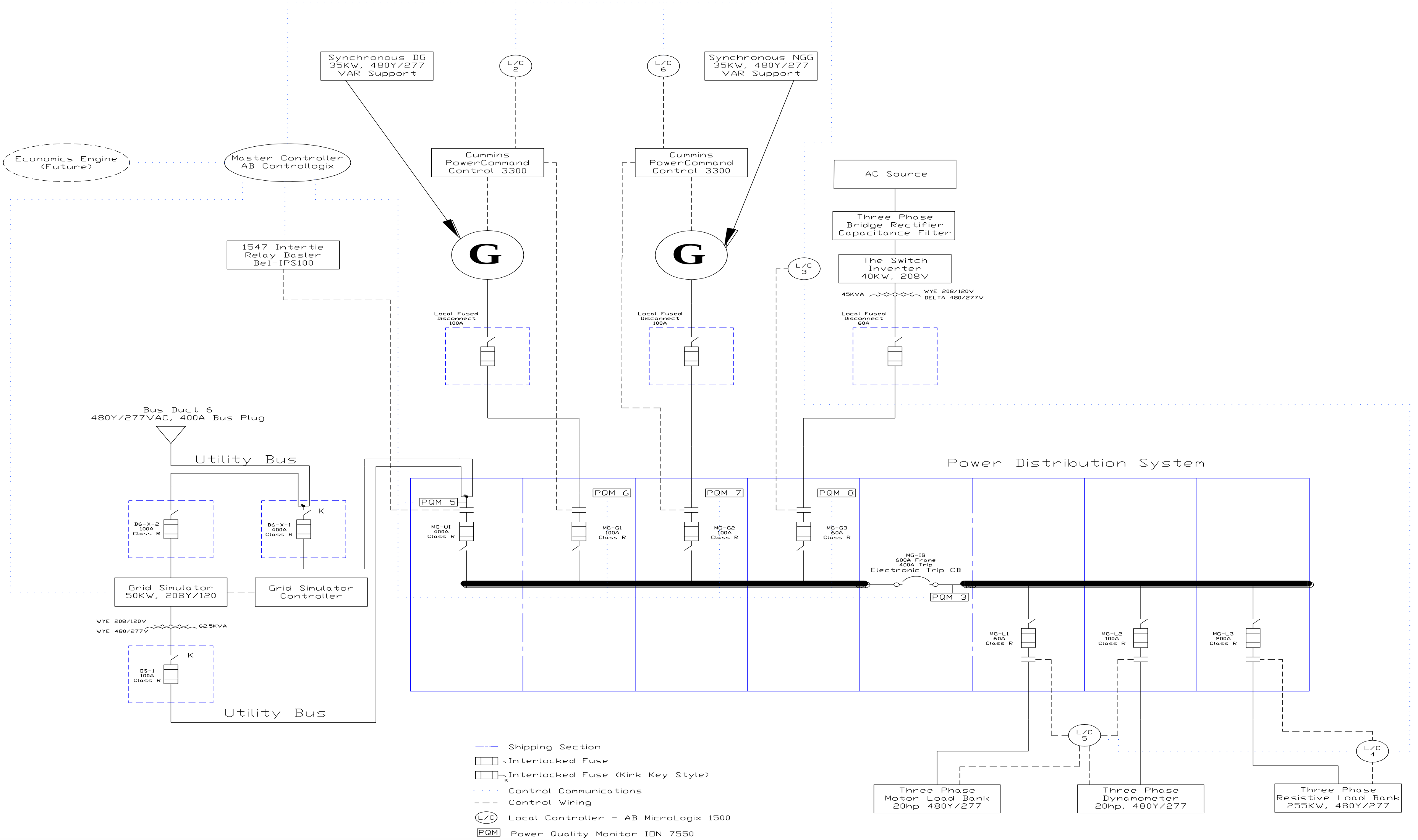
- Microgrid Master and Local Controllers
  - Programmable Logic Controllers (PLCs) to coordinate and implement intelligent control of distributed sources and loads.
  - Redundant controllers to avoid single points of failure.
  - LabView based-HMI to provide oversite and configure testing
  - COTS components
- Generator Controls
  - One main controller per generator simplifies synchronization of conventional generation sources compared to configuring and integrating three additional control relays per generator.
  - COTS components

Microgrid Approach

- Software Modeling -
  - Prepare software models of individual sources and loads to predict impact to electrical system.
  - Create a microgrid system model from the individual component models to predict system performance.
  - Validate accuracy and correct simulation models
  - Create test cases and control strategies based upon system performance/limitations predicted and validated by models.

- Control Algorithms –
  - Monitor system health and intelligently control sources and loads
  - Coordinated control between controllers for system stability

System One-line



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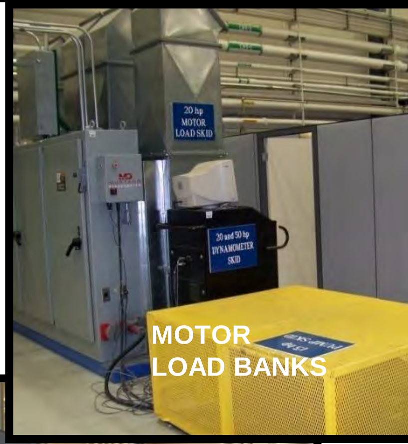
Distributed Sources and Loads

- Distributed Sources
  - (1) 35 kW Diesel Generator
  - (1) 35 kW Natural Gas Generator
  - (1) 40kW Renewable Energy Inverter
  - (1) 400A Utility Service
  - (1) 50kW Grid Simulator

- Distributed Loads
  - (4) 5 hp three phase motors
  - (1) 20hp dynamometer
  - (1) 225 kW Resistive Load Bank



Test Plan

- Component Model Validation
  - (1) 35 kW Diesel Generator
  - (1) 35 kW Natural Gas Generator
  - (1) 40kW Renewable Energy Inverter
  - (1) 50kW Grid Simulator
  - (4) 5 hp three phase motors
  - (1) 20hp dynamometer
  - (1) 225 kW Resistive Load Bank

- System Model Validation and Analysis

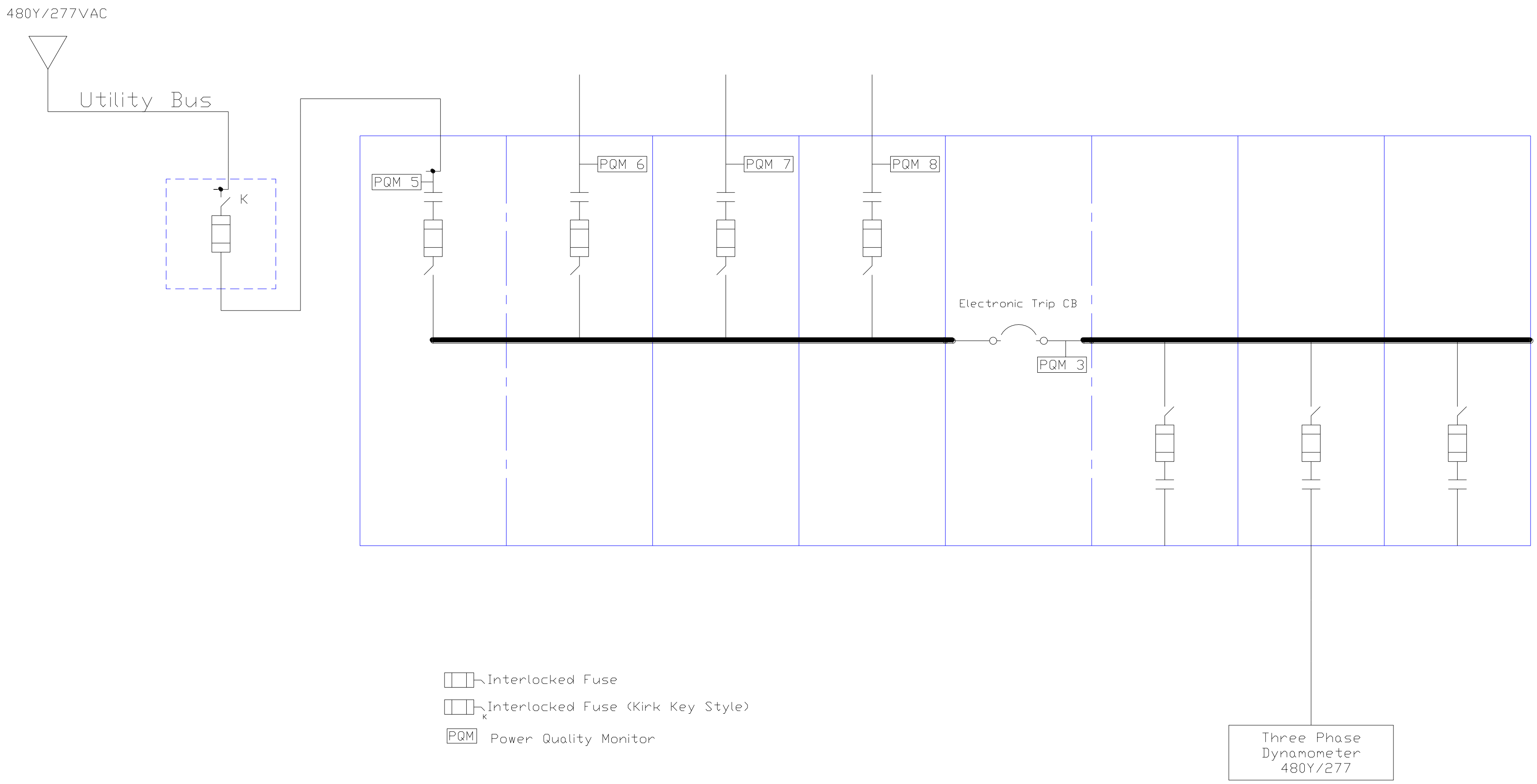
- System Stability Testing and Analysis

Test Results Summary
Steady State Accuracy: 90+%

Test	Description	Real Power % Accuracy	Reactive Power % Accuracy
TC1-1	RLB Component Validation Test	>91% (steady state at load bus)	N/A
TC1-2	MLB Component Validation Test	N/A	>95% (steady state at load bus)
TC1-3	20 hp Motor w/ Dynamometer Component Validation Test	>95% (steady state at load bus)	>90% (steady state at load bus)
TC1-4	Inverter Component Validation Test	>99% (steady state at inverter bus)	N/A
TC1-5	DG Component Validation Test	>92% (steady state at load bus)	>90% (steady state at load bus)
TC1-6	NGG Component Validation Test	>92% (steady state at load bus)	>90% (steady state at load bus)
TC2-1	Grid-connected System Validation Test	>97% (steady state at load bus)	>92% (steady state at load bus)

Dyno Component Test One-line

Connected: Utility, 20Hp Dynamometer



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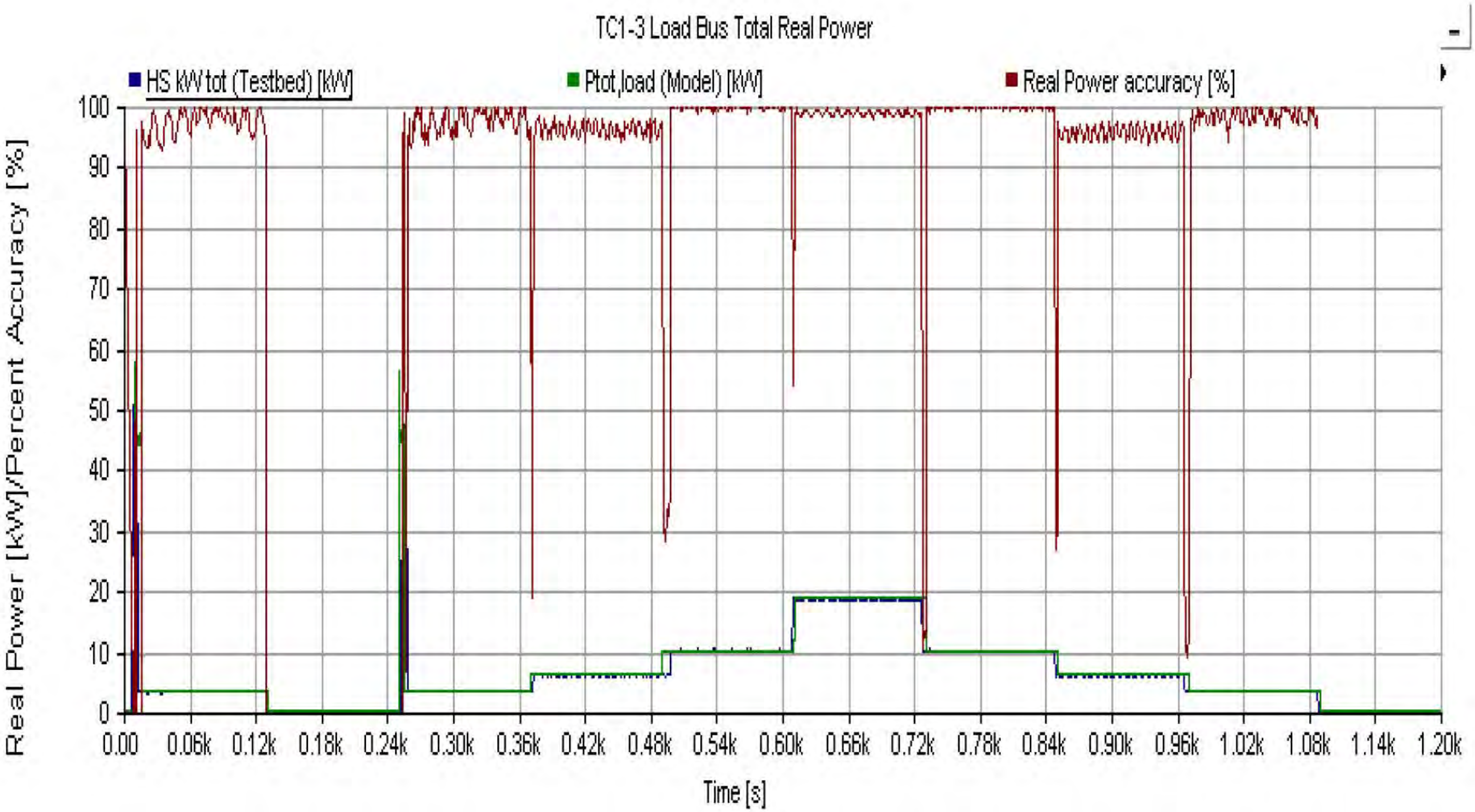
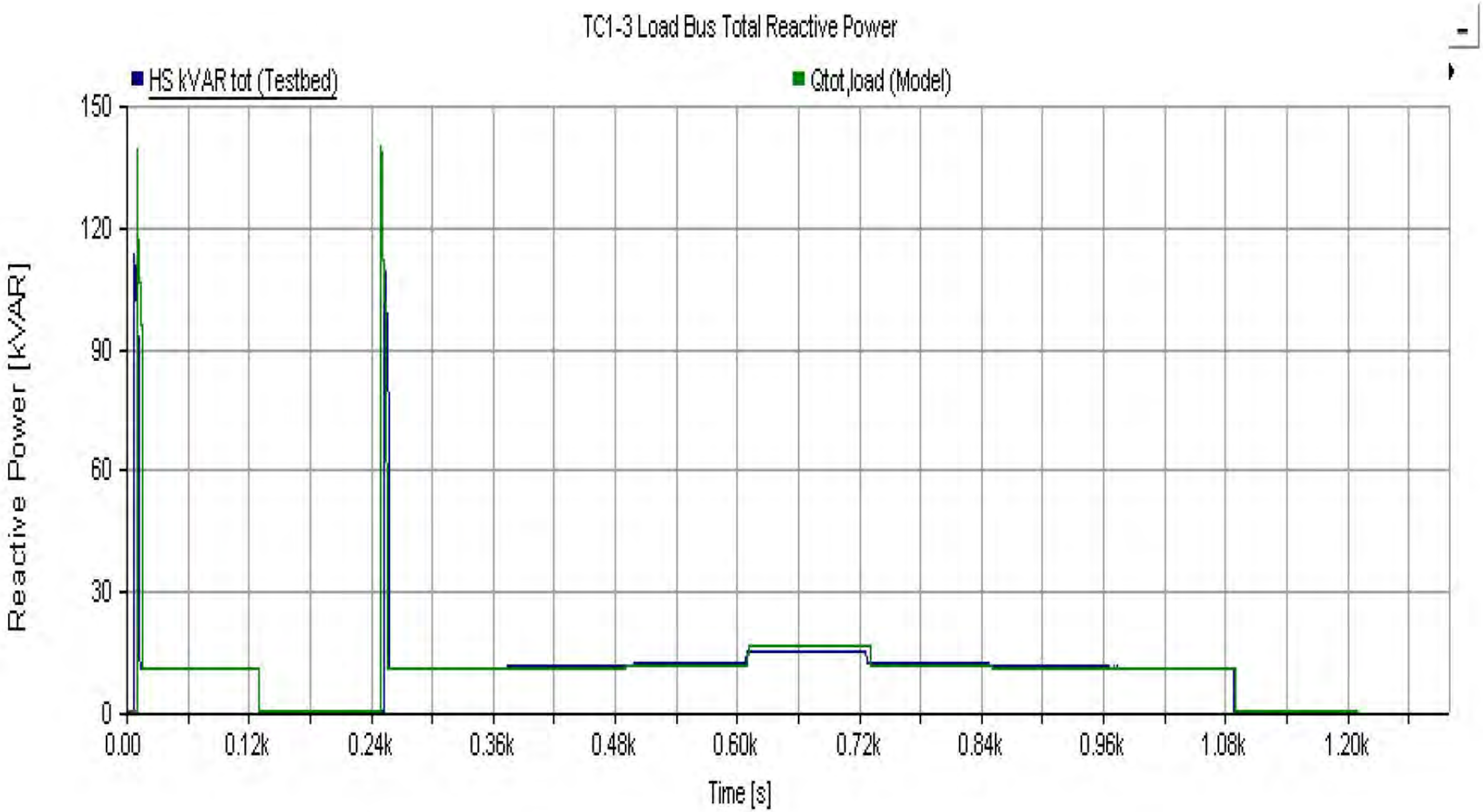
Dyno Component Test Results
Model kW vs Actual - 95+% Accurate



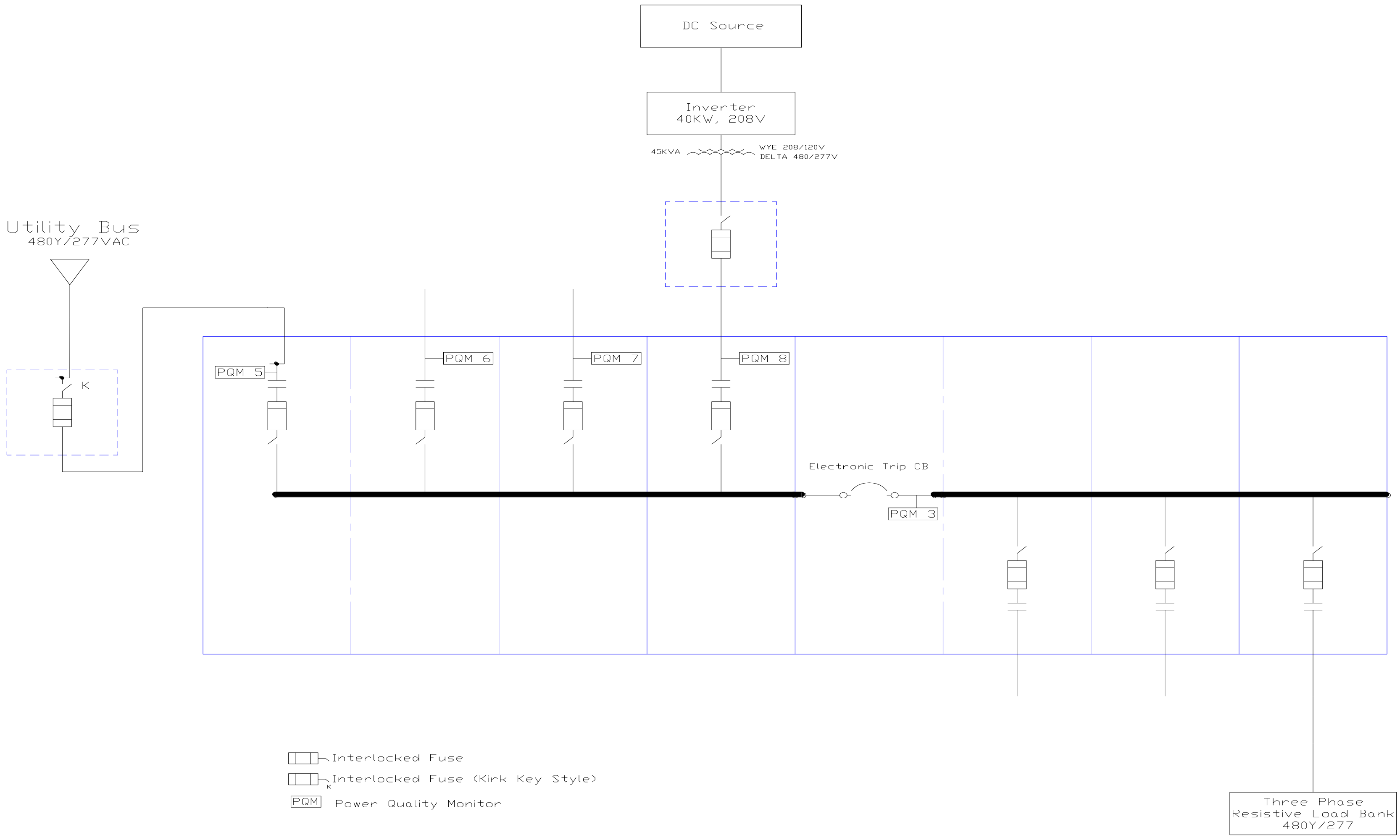
Dyno Component Test Results

Note: Identify System Stress Points, VAR Requirements



Inverter Component Test One-Line

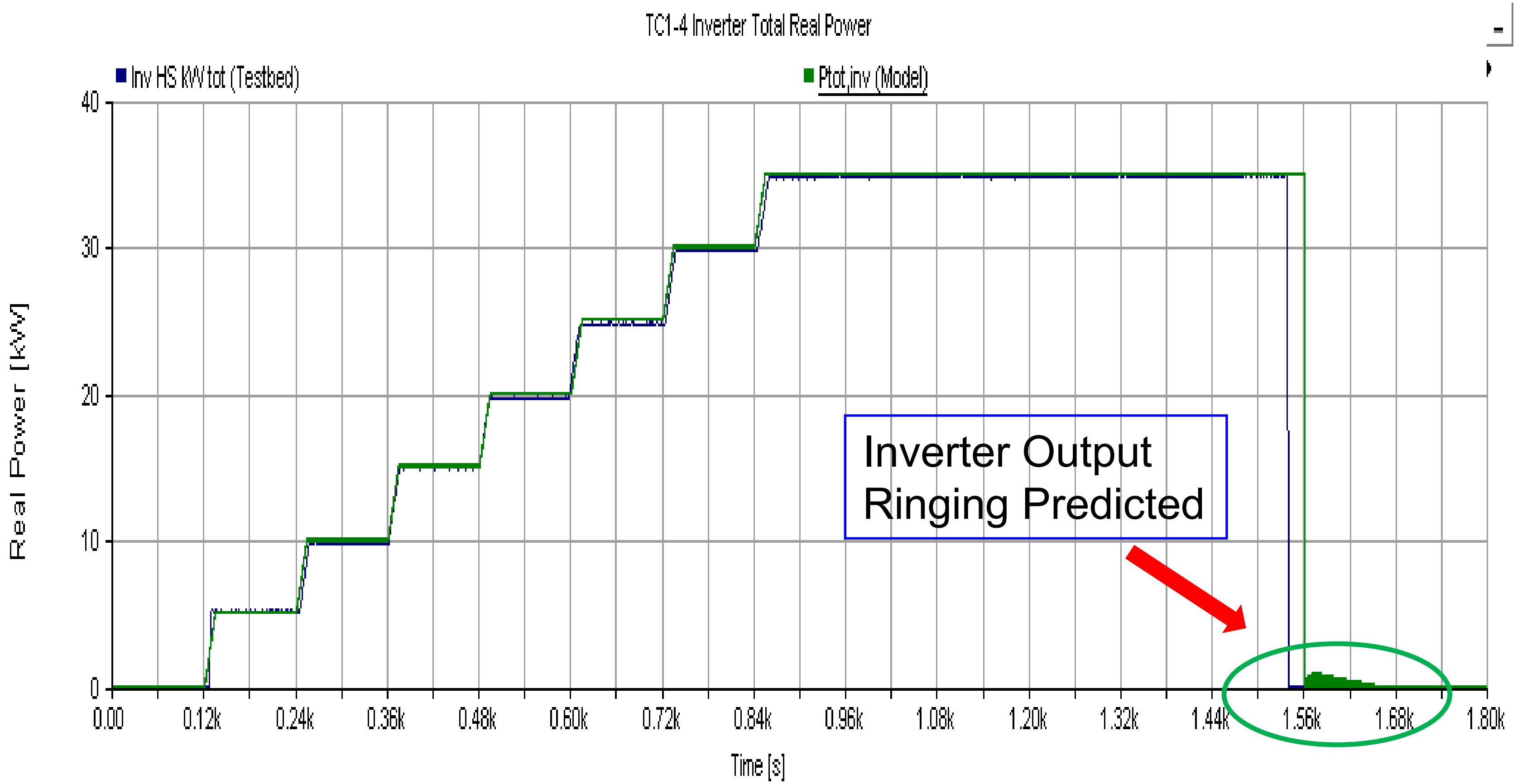
Connected: Utility, Inverter



Inverter Component Test Results

Initial Model kW vs Actual -

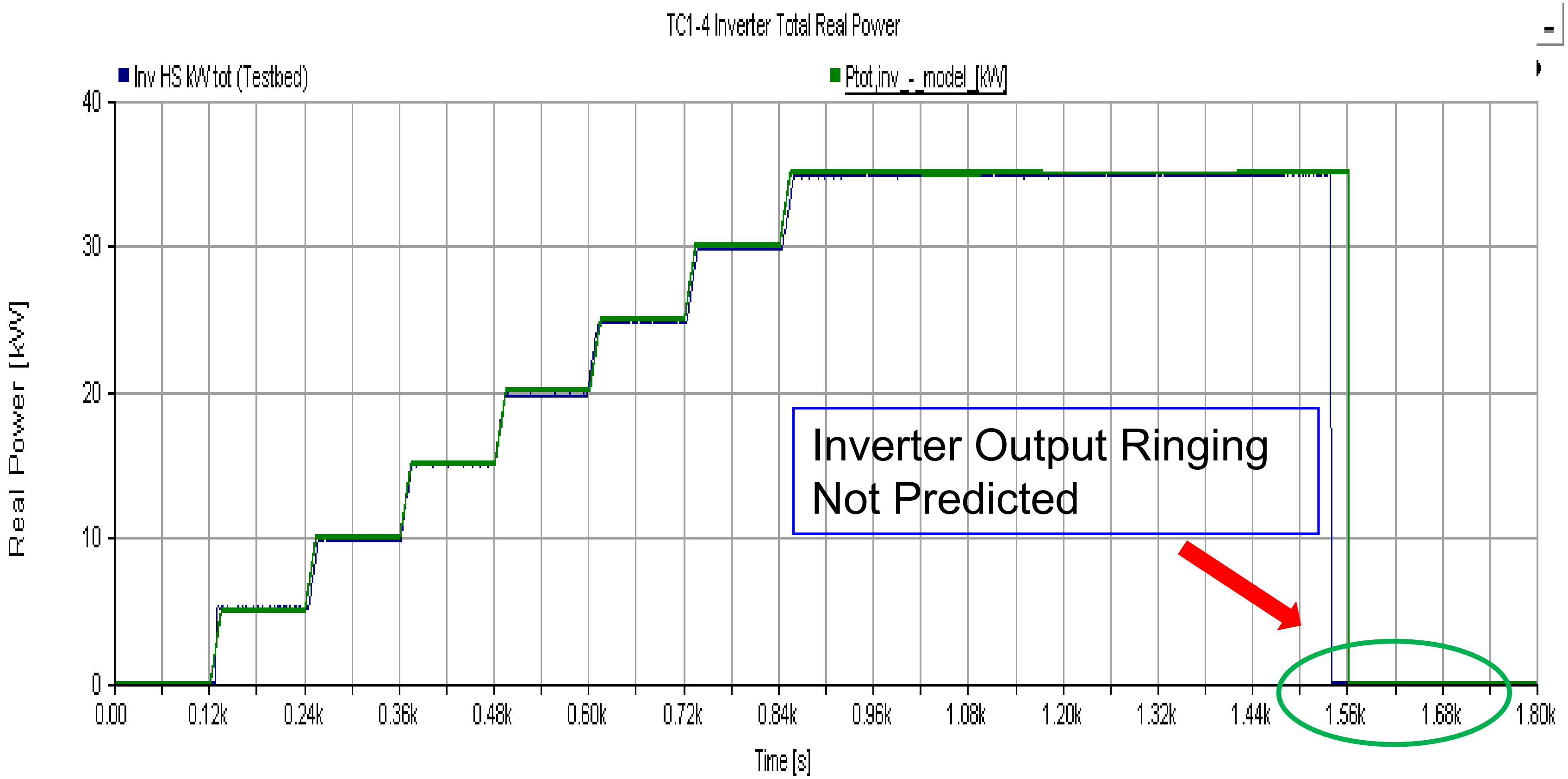
Note: False Output Ringing Predicted by Model



Inverter Component Test Results

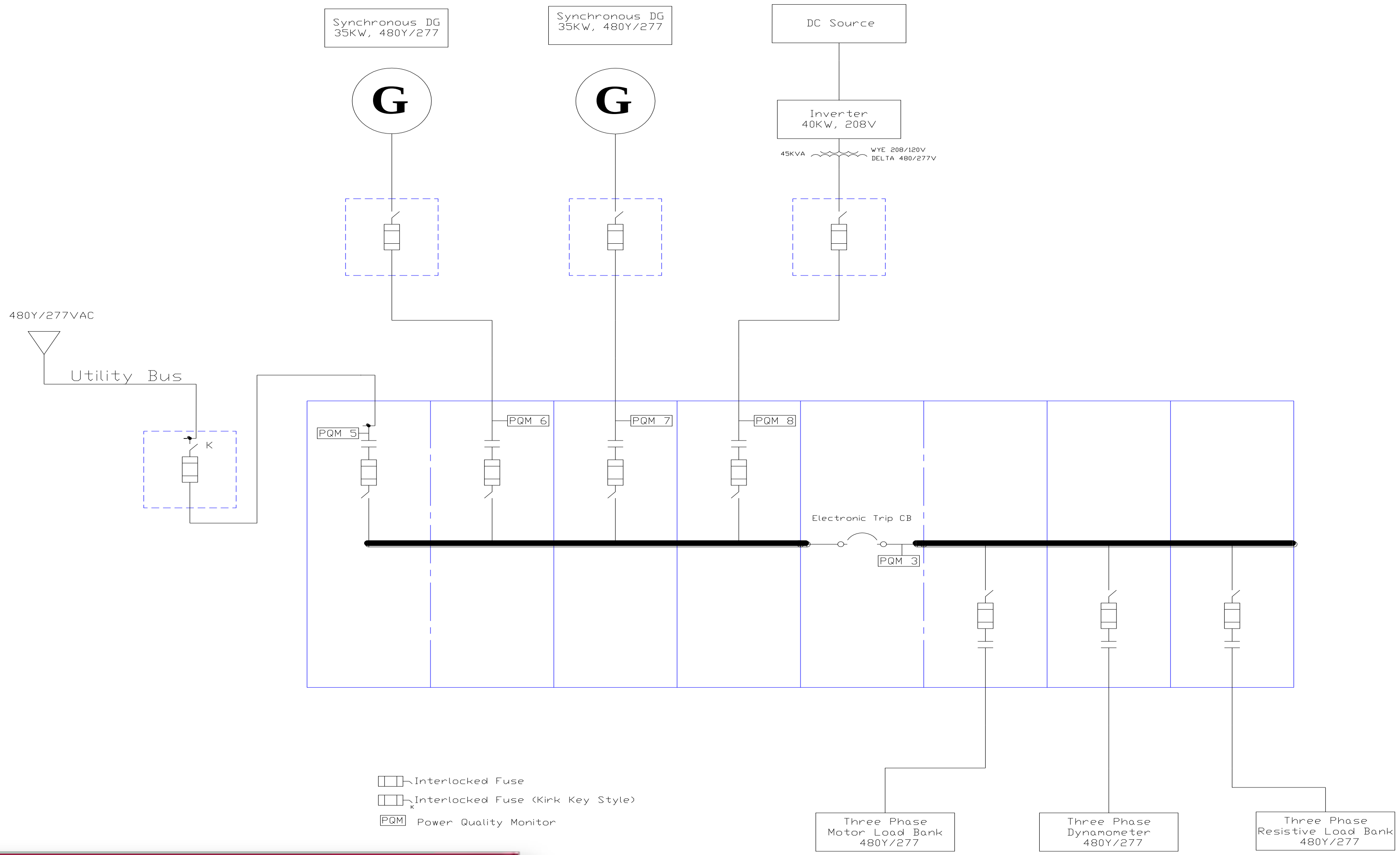
Revised Model kW vs Actual

Note: Model Configuration Impacts Simulation Software Results



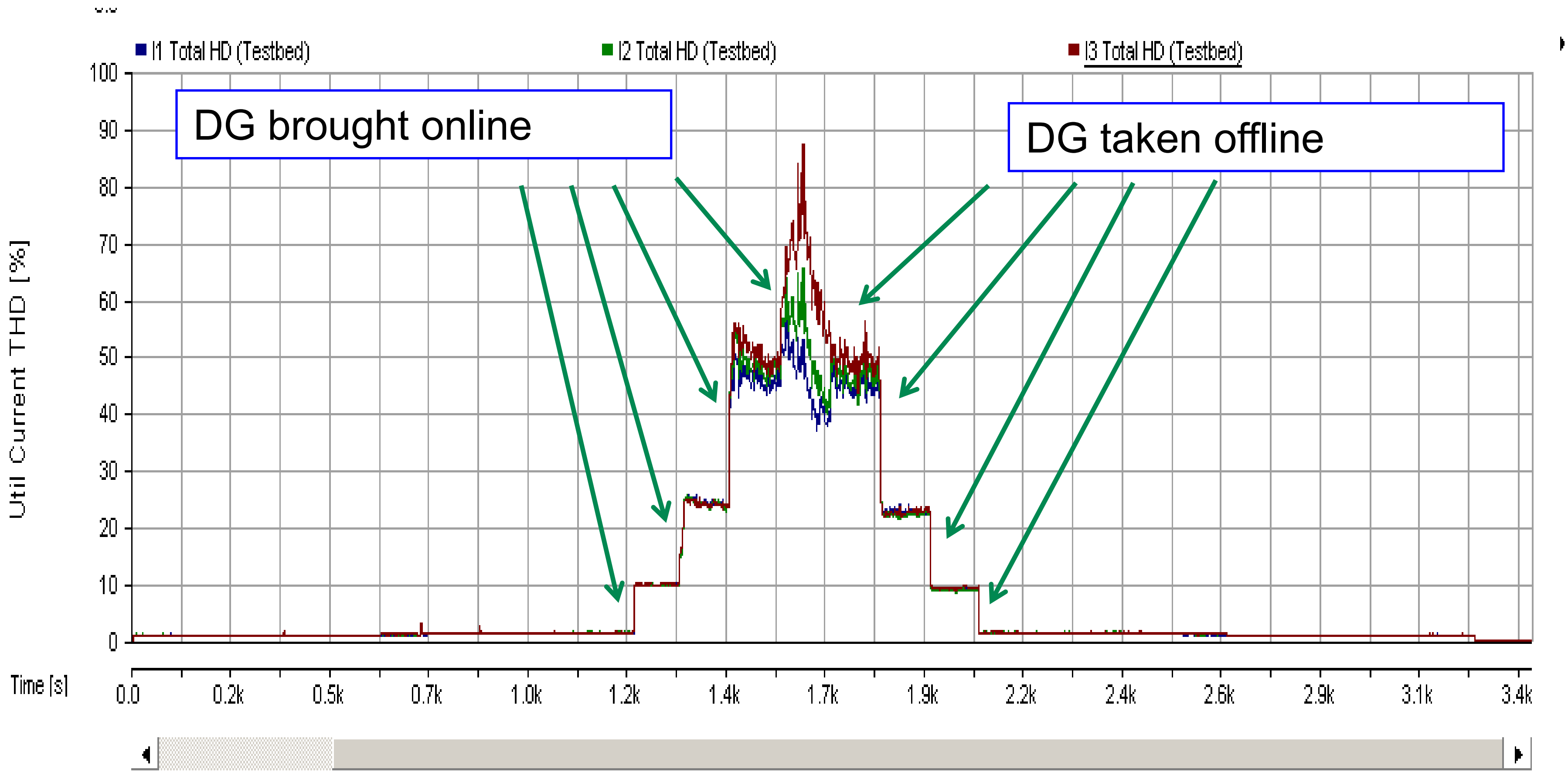
System Test One-line

Connected: Utility, Gensets, Inverter, RLB, MLB, Dyno



System Test Results

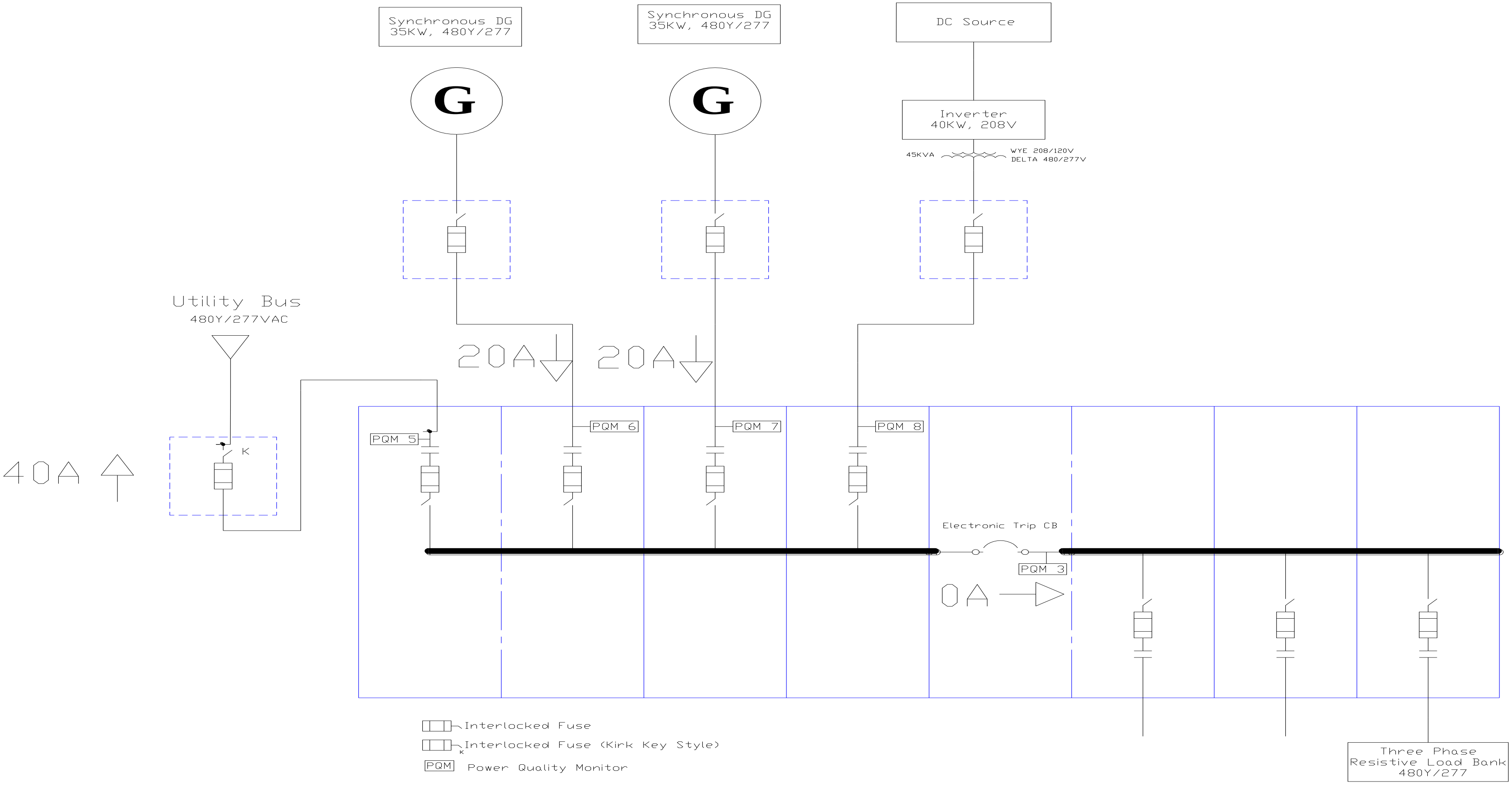
Utility Current THD Measurements
Note: Confirm THD



System Test Results

Utility Neutral Current Measurements

Note: Confirm Neutral Current Direction



System Test Results

Note: Neutral Current Solutions

- Transformer Isolation
  - Delta-Wye Transformer traps 3rd order harmonics
- Three Phase Harmonic Filter
  - Wye – Delta Transformer to eliminate zero sequence currents
- Neutral Reactor
  - Tuned reactor to block 3rd order currents only
- Neutral Grounding
  - Establish one neutral path to ground
  - Confirm neutral grounding when isolated from utility

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